(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
11 January 2001 (11.01.2001)

PCT

(10) International Publication Number
WO 01/03464 A1

(51) International Patent Classification[7]: H04Q 7/38

(21) International Application Number: PCT/US00/18599

(22) International Filing Date: 6 July 2000 (06.07.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
09/348,442 7 July 1999 (07.07.1999) US

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(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE,

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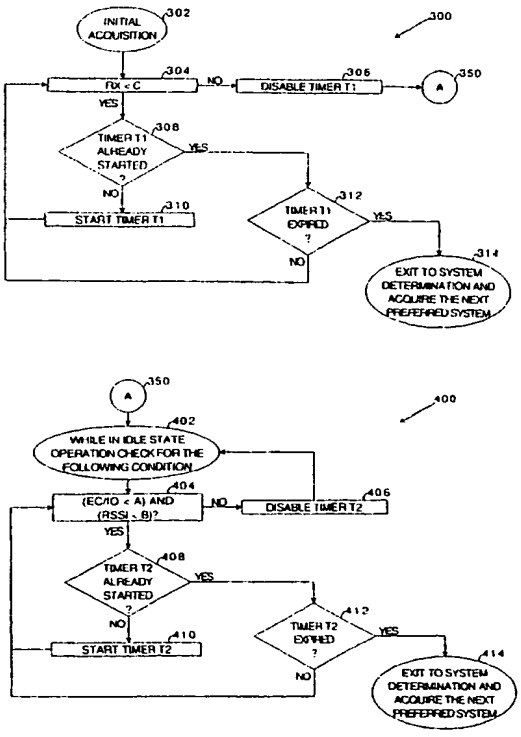
(54) Title: SYSTEM AND METHOD FOR EDGE OF COVERAGE DETECTION IN A WIRELESS COMMUNICATION DEVICE



(57) Abstract: A method to enhance performance of a dual-mode or dual-band mobile phone includes, after the phone has initially connected to a CDMA wireless network, monitoring (304) a level of total power received by the phone. This power level is compared (304) to a preset threshold level (C). If the power level remains below the threshold level for over two seconds (308, 312), the dual-mode or dual-band phone switches (314) to an AMPS or other network retrieved from the preferred roaming list that is stored in the phone. If the power level is above the threshold, the phone moves into the idle state (402). Once in the idle state, both the pilot strength and Received Signal Strength Indication are monitored (404). If both of these levels are below respective thresholds for over eight seconds (408, 412), the phone switches (414) to another network stored in the preferred roaming list. If the mobile phone is not a dual-mode or dual-band phone, the mobile phone can perform similar measurements and switch between service provider systems compatible with the mobile phone.

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BNSDOCID: <WO___0103464A1_I_>

IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:

— *With international search report.*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

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SYSTEM AND METHOD FOR EDGE OF COVERAGE DETECTION IN A WIRELESS COMMUNICATION DEVICE

I. Field of the Invention

The present invention is related generally to a wireless communication device and, more particularly, to a system and method to detect the edge of service in a first communication system and obtain coverage in a second communication system for the wireless communication device.

II. Background of the Invention

Wireless communication devices, such as cellular telephones, are widely used as a replacement for and in addition to conventional telephone systems. In addition to providing the functionality of a conventional telephone, wireless communication devices offer the advantage of portability, thus enabling the user to establish a wireless communication link between virtually any two locations on Earth.

Wireless communication devices operate within regions or cells of coverage each having a geographic coverage area. A transmitter and receiver, centrally located within each cell, is controlled such that the effective coverage area of the cell just overlaps with adjacent cells. Cells for analog wireless communication devices and cells for digital wireless communication devices may not be coextensive. That is, although a given city may have complete analog cellular coverage and complete digital cellular coverage, analog and digital cell boundaries are usually different.

Typically, wireless communication devices have lower levels of performance when they are near the edge of a cell than when they are not near an edge. Therefore, when traveling from one cell to another, performance of a wireless communication device tends to degrade while approaching the edge of a first cell and does not return to full performance until the wireless communication device is away from the edge of the second cell. This is an especially important effect when the cell is on the edge of the coverage area, where there is no second cell to move into. This degradation is especially

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frustrating when the edge of one system's coverage area is the beginning of another system's coverage area. Thus, it is apparent that there is a need to increase the performance of wireless communication devices when located near the edge of a cell, and especially at the edge of a coverage area. The present invention provides this and other advantages as will be apparent from the following figures and accompanying description.

SUMMARY OF THE INVENTION

In one aspect of the present invention, a system and method to enhance performance of a mobile phone is presented. The method includes monitoring a level of performance of the mobile telephone communicating with a first service provider system, comparing the first performance level with a first threshold level and, if the first performance level remains below the first threshold level for a first duration of time, switching the telephone to a second service provider system.

In another aspect of the invention, when the mobile phone is in an idle mode, first and second performance levels are monitored. If the first performance level falls below a first threshold or the second performance level falls below a second threshold a timer is started. If both the first and second performance levels exceed their respective thresholds, the timer is reset, but if the timer runs long enough to exceed a preset time limit, the mobile telephone switches to another service provider system. If the mobile phone is a dual-mode or dual-band phone, it is possible to switch between modes or bands when switching service provider systems.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a functional block diagram of an exemplary embodiment of the wireless communication device of the present invention.

FIG. 2 illustrates a representative coverage diagram for wireless communication systems.

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FIG. 3 is a flowchart indicating different states of a wireless communication device and a base station for a wireless communication device.

FIG. 4 is a flowchart showing the logical flow of an embodiment of the present invention.

FIG. 5 is a flowchart indicating logical flow for another embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention is directed to a technique for increasing the performance of a wireless communication device near the edge of coverage when another wireless system is available. Most populated areas of the United States and of the world are covered by at least one type of wireless communication service. One type of such service is Advanced Mobile Phone Service (AMPS). AMPS is an analog cellular phone system and is well known in the art. Additionally, some areas may have Personal Communication Service (PCS), or a digital cellular telephone system or both. One form of digital cellular telephone system is Code Division Multiple Access (CDMA), also well known in the art.

Several factors contribute to the performance of a wireless communication device, such as distance from the cellular base station transceiver subsystem (BTS), BTS transmitter power, geographical considerations, and proximity to buildings or other reflective surfaces among other factors. When the wireless communication device is traveling between cells, performance gradually degrades as the wireless communication device approaches the edge of the current cell and gradually increases once the wireless communication device establishes communication with the BTS of an adjacent cell and moves away from the boundary between the cells and closer to the BTS in the newly acquired cell. The process of switching communication from one cell to another is called a handoff. Many types of handoffs, such as hard and soft handoffs, are known in the art and need not be described in detail herein.

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Depending on the location of the cell boundaries, it may be the case that the wireless communication device is handing off between two CDMA cells (and thus experiencing poor quality while near the boundaries of the CDMA cells) while also located in the middle of an AMPS cell where the wireless communication device would be experiencing excellent service if the device were currently using AMPS.

Occasionally, CDMA systems may have a link imbalance where a forward link, (*i.e.*, the data link sent from the BTS to a wireless communication device such as a mobile or cell phone), is much stronger than the reverse link (*i.e.*, the data from the wireless communication device back to the BTS). On these occasions, it is possible for the wireless communication device to receive paging messages from the BTS indicating CDMA coverage is available, even though the mobile phone is unable to communicate with the BTS over the reverse link at a sufficient level to make or receive a call. This can be frustrating for the operator of the mobile phone. It is also particularly frustrating to carriers that operate both CDMA and AMPS systems because the mobile phone may be in a location where it could receive good AMPS coverage. While a carrier that only operates CDMA systems may desire that the mobile phone stay with a CDMA system at all times, a carrier that operates both AMPS and CDMA systems prefers the mobile phone to connect to the better service when performance with the current system degrades. For instance, the mobile phone may switch from CDMA to AMPS when performance is deficient in the CDMA system but would be adequate in the AMPS system. The present invention allows the wireless communication device to determine it is in a weak coverage area and try other systems in order to establish better service.

The present invention is embodied in a system **100** illustrated in the functional block diagram of FIG. 1. The system **100** includes a central processing unit (CPU) **102** which controls operation of the system. A memory **104**, which may include both read-only memory (ROM) and random access memory (RAM), provides instructions and data to the CPU **102**. A portion of the memory **104** may also include non-volatile random access memory (NVRAM).

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The system **100**, which is typically embodied in a wireless communication device such as a cellular telephone, also includes a housing **106** that contains a transmitter **108** and a receiver **110** to allow transmission and reception of data, such as audio communications, between the system **100** and a remote location, such as a cell site controller or BTS (see FIG. 2). The transmitter **108** and receiver **110** may be combined into a transceiver **112**. An antenna **114** is attached to the housing **106** and electrically coupled to the transceiver **112**. The operation of the transmitter **108**, receiver **110**, and antenna **114** is well known in the art and need not be described herein.

The system **100** also includes a signal detector **116** used to detect and quantify the level of signals received by the transceiver **112**. The signal detector **116** detects such signals as total energy, pilot energy per pseudonoise (PN) chips, power spectral density, and other signals, as is known in the art. Various indicators and values are calculated by the signal detector **116** for use in the system **100**, as described in further detail below.

A set of timers **118** works in conjunction with a pilot strength processor **120**, a pilot received power processor **122**, and a total received power processor **124**. By measuring the levels of the signals received and processing these signals, the system **100** can determine the quality of the communication channel between the wireless communication device and its BTS.

The pilot strength processor **120** receives a pilot strength indicator (*Ec/Io*) from the signal detector **116**. The signal detector **116** divides the ratio of pilot energy per PN chip (*Ec*) by the total power spectral density received at the transceiver **112** (*Io*). This ratio of pilot energy to overall received energy is called "pilot strength," as is known in the art. Also as known in the art, the pilot strength depends on loading conditions of an active cell and adjacent cells, and thus is an indication of traffic load in a particular cell.

The total received power processor **124** uses a variable *Rx* that is detected and quantified at the signal detector **116**. The total received power (*Rx*) is a measure of all power received at the transceiver **112**. It includes thermal noise, interference from other callers and a pilot signal transmitted to that particular transceiver **112**. A total of all this energy received is stored in the variable *Rx* indicating total received power.

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The pilot received power processor **122** receives a Received Signal Strength Indicator (RSSI) from the signal detector **116**. The RSSI indicates the pilot received power and, in an exemplary embodiment, is calculated by adding the total received power (*Rx*) with the (*Ec/Io*), as is known in the art. The RSSI is independent of system loading and variation in the RSSI indicates forward link path loss changes. These path loss changes are important in determining when to switch service, described in detail below.

A state changer **126** of the system **100** controls the state of the wireless communication device based on a current state and additional signals received by the transceiver **112** and detected by the signal detector **116**. The wireless communication device is capable of operating in any one of a number of states, as later described with reference to FIG. 3.

The system **100** also includes a system determinator **128** used to control the wireless communication device and determine which service provider system the wireless communication device should transfer to when it determines the current service provider system is inadequate.

The various components of the system **100** are coupled together by a bus system **130** which may include a power bus, a control signal bus, and a status signal bus in addition to a data bus. However, for the sake of clarity, the various busses are illustrated in FIG. 1 as the bus system **130**. One skilled in the art will appreciate that the system **100** illustrated in FIG. 1 is a functional block diagram rather than a listing of specific components. For example, although the pilot strength processor **120**, pilot received power processor **122**, and the total received power processor **124** are illustrated as three separate blocks within the system **100**, they may in fact be embodied in one physical component, such as a digital signal processor (DSP). They may also reside as program codes in the memory **104** and operated on by the CPU **102**. The same considerations apply to the other components listed in system **100** of FIG. 1.

Operation of components shown in the system **100** of FIG. 1 will be explained with reference to FIGs. 2-5. FIG. 2 shows a coverage diagram **150** including multiple boundaries of wireless communication cells. FIG. 2 is not drawn to scale, but is merely intended to illustrate areas of coverage and boundaries between those areas of coverage. The diagram **150** includes a first

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CDMA cell **152** that shares a common boundary **156** with an adjacent CDMA cell **154**. Although the boundary **156** is illustrated as a straight line between the CDMA cell **152** and the CDMA cell **154**, it is well understood that the areas of coverage in the CDMA cells overlap and that the boundary **156** depends on many factors, such as geographic terrain, buildings, and the like. For the sake of clarity in understanding the present invention, the boundary **156** in FIG. 2 is shown as a straight line.

The CDMA cell **152** contains a BTS **162** labeled CDMA BTS-1. The BTS **162** is located in approximately the center of the CDMA cell **152**. The CDMA cell **154** likewise contains a BTS **164** located roughly in the center of that CDMA cell **154** and labeled CDMA BTS-2. As stated above, some of the factors that determine the distance of the borders of the cells **152, 154** from their respective BTS' include antenna shape and orientation, terrain, presence or absence of reflective surfaces, and environmental factors such as weather.

An AMPS cell **158** is shown having noncontiguous borders with the CDMA cells **152** and **154**. The size of the cells **152, 154,** and **158** does not indicate actual relative size, or orientation, but is shown only for illustration. As is known in the art, CDMA cells are typically smaller than AMPS cells, but this is not relevant for purposes of explanation of the invention as the invention will operate in cells of any size and orientation.

The AMPS cell **158** includes a BTS **168** in its approximate center, labeled AMPS BTS-1. The AMPS BTS **168** differs from the CDMA BTSs **162** and **164** principally in the frequencies transmitted and received as well as the modulation format. The AMPS BTS **168** transmits and receives an analog signal on a first set of frequencies while the CDMA BTSs **162** and **164** transmit and receive digital signals on a separate set of frequencies. These and other differences between the AMPS system and a digital system, such as CDMA, are well known in the art and need not be described herein.

In FIG 2, a wireless communication device such as a mobile or mobile phone **160** is depicted as being transported by an automobile in CDMA cell **152**. The mobile phone **160** is approaching the border **156**. As described above, the quality of the wireless communication between the mobile phone **160** and the BTS **162** degrades at the edge of the CDMA cell **152**. Although CDMA

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technology includes error correction to make up for some data lost in transmission, occasionally the quality of service degrades to the point that communication is impossible.

In some markets, the same carrier, for instance, AT&T or Ameritech will own both the CDMA systems and the AMPS systems for a given geographical area. Although most mobile phones originally produced for the AMPS system are not capable of communicating with a CDMA system, the reverse is not always true. Specifically, many mobile phones can communicate with both the CDMA and AMPS BTSs. These phones are known as dual-mode phones. CDMA systems operate in two frequency bands, the cellular band (800 MHz) and the PCS band (1900 MHz). AMPS systems also operate in the 800 MHz band. A PCS phone which also operates in the 800 MHz band, whether in cellular mode or AMPS mode, is known as a dual-band phone.

If the same carrier owns both an AMPS system and a CDMA system within the same geographical area, the carrier wants to provide the best service to the mobile phone **160** irrespective of which system (AMPS or CDMA) on which the phone is currently operating. For instance, when the mobile phone **160** is nearing the edge of a CDMA system, the system **100** can search for the best available system, regardless of type. This is a radical change from previous cell phone systems that required the mobile phone **160** to stay on one system regardless of quality because that was all that was available.

As depicted in FIG. 2, the mobile phone **160** is nearing the border **156**. It is likely experiencing a poor connection either from the BTS **162** or as it is establishing a new connection with BTS **164**. However, note that the AMPS BTS station **168**, given its proximity to the mobile phone **160**, is likely able to provide a good level of service. Unfortunately, conventional cell phones are designed to remain with one system as long as one is available. In this example, a cell phone of the prior art will stay with the CDMA system, communicating with the BTSs **162** and **164** regardless of how poor the signal becomes. As described below, embodiments of the present invention are able to measure factors indicative of poor cellular communication quality, and if the mobile phone **160** is experiencing poor quality, search for another cellular system as directed by the carrier.

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In FIG. 3, a state diagram **200** shows different operational states for a base station **210** and the mobile phone **160**. These states are known in the art and will be discussed only briefly. In an initialization state **222**, the mobile phone **160** receives a pilot signal and synchronization signals from the base station **210**, which is in a pilot and sync channel processing state **212**. Once the mobile phone **160** is initialized, it enters an idle state **224**. While the mobile phone **160** is in the idle state **224**, the base station **210** is in a paging channel processing state **214** and sends paging messages and overhead information to the mobile phone. That is, the mobile phone **160** monitors and processes Paging Channel messages and overhead information sent by the base station. The mobile phone **160** remains in the idle state **224** once it has powered up and initialized while it is waiting to place a call, or waiting for a call to be placed to it. When the mobile phone **160** makes or receives a call, it changes from the idle state **224** to a system access state **226**. In the system access state **226**, the mobile phone **160** requests a channel from the base station **210**. The base station **210** responds to set up the channel in an access channel processing state **216**. Once the traffic channel is set up between the base station **210** and the mobile phone **160**, the mobile phone enters a traffic channel state **228**, while the base station **210** enters a traffic channel processing state **218**. While in these states, the mobile phone **160** is sending and receiving data, such as voice data to and from the base station **210**.

Embodiments of the invention are directed to two main systems maintained in the mobile phone **160**. In the first embodiment, described with reference to FIG. 4 and related text, the mobile phone **160** is just entering a service provider system. This can occur when the mobile phone **160** is first turned on, or is first attempting to communicate with a BTS. The mobile phone **160** first determines whether it is receiving sufficient total power to permit a satisfactory level of performance by the cell phone. If so, the mobile phone **160** enters the idle state **224** for further monitoring. If not enough total power is reaching the mobile phone **160**, it exits the first service provider system to find a better service provider system. In the second embodiment, while in the idle state **224**, the mobile phone **160** monitors the pilot strength (Ec/Io) and the pilot received power (RSSI) to determine if both are below their respective

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predetermined thresholds. If both of these levels remain below the respective thresholds too long, the mobile phone **160** searches for another service provider system. This second embodiment is described with respect to FIG. 5 and the related text.

A flowchart **300** of FIG. 4 is performed while the mobile phone **160** is in the initialization state **222** (see FIG. 3). The flowchart **300** begins with an initial acquisition **302**. The mobile phone **160** will be in the initial acquisition **302** if the phone just acquired a CDMA service provider system, for instance, if the mobile phone **160** was just turned on, reset, or just changed from another service provider system. In the initial acquisition step **302**, the mobile phone **160** is primarily interested in knowing how much total received power (*Rx*) is present. It determines this information using the total received power processor **124** (see FIG. 1).

After the mobile phone **160** has acquired a CDMA service provider system in the initial acquisition **302**, the mobile phone compares the total received power *Rx*, to a threshold *C* in a comparison step **304**. This comparison is performed by the total received power processor **124** of FIG. 1. In an exemplary embodiment, total received power is measured in dBm, and includes CDMA signals, noise, and interference. CDMA signals are those signals sent from the base station **210** (see FIG. 3) directed to the particular mobile phone **160**. Interference is the sum of signals being transmitted from any base station **210** or from any other mobile phones **160** that is received by the transceiver **112** (see FIG. 1) and quantified by the signal detector **116**. Noise is any other signal detected at the transceiver **112** and can include environmental noise and/or disruptions in the electromagnetic spectrum.

In comparison **304** of FIG. 4, the total received power processor **124** determines whether or not the total received power *Rx* is less than the threshold *C*. The threshold *C* can be any appropriate value, and by way of example, is set at -105 dBm for CDMA PCS and -107 dBm for CDMA cellular systems. If the total received power processor **124** determines that *Rx* is greater than *C*, the output from comparison **304** is NO and the system **100** progresses to step **306** where a timer t1 is disabled. The timer t1 is located within the timers **118** of FIG. 1. In this particular instance, where the total received power in

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comparison **304** is initially greater than *C*, the timer t1 never starts. Regardless of whether the timer t1 was ever running, once the timer t1 is disabled in step **306**, the system **100** progresses to an initial step **350** depicted in FIG. 5.

Returning to comparison **304**, if the total received power *Rx* is less than *C*, the result of comparison **304** is YES and the system **100** enters a decision **308**. In decision **308**, a query is sent to the timers **118** of FIG. 1 to determine if the timer t1 had been previously started. If the timer t1 had not already been started, it is then immediately started in step **310**, and the system **100** loops back to the comparison **304**, where the total received power *Rx* is again checked against the threshold *C*.

If by this time the total received power *Rx* is above the threshold *C*, the system **100** exits comparison **304** with a NO response, as described above. However, if the total received power *Rx* remains below the threshold *C* in comparison **304**, the system **100** again enters decision **308**. Since the timer t1 is already running, the system **100** checks to see if the timer t1 has expired in decision **312**. In an exemplary embodiment, the timer t1 will expire two seconds after it starts. If the timer t1 has not yet expired, the result of decision **312** is NO and the system **100** loops back to comparison **304** where the total received power *Rx* is again checked against the threshold *C*.

As an overview to the flowchart **300**, once the mobile phone **160** enters the initial acquisition state **302**, the total received power processor **124** evaluates the total received power *Rx* signal. If at any time within the time period of the timer t1 (*e.g.*, two seconds), the total received power *Rx* climbs above the threshold *C*, the system **100** exits to step **350**, shown in FIG. 5. If, however, the total received power *Rx* is below the threshold *C*, for more than two seconds, the system **100** exits to step **314**, described below.

In step **314**, the system **100** forces the mobile phone **160** to abandon the present service provider system to try to connect to a better one. This system determination is performed by the system determinator **128** of FIG. 1. This system determination can be performed in a number of ways. For instance, in an exemplary embodiment, a list of preferred service provider systems is kept in a preferred roaming list (not shown). The preferred roaming list is a list of frequencies and bands used in different parts of the country. A

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telephone manufacturer will originally program the system determinator **128** with a generic preferred roaming list, containing default frequencies within the frequency tables. When the mobile phone **160** is purchased by a customer, the carrier servicing the mobile phone **160** may reprogram the preferred roaming list for the benefit of the carrier. For example, the carrier could program the preferred roaming list to attempt to contact their own service provider systems first, and then contact all the service provider systems with whom they have contracts, and then try any available service provider system. Alternatively, the carrier may program the preferred roaming list to try all of the CDMA service provider systems prior to switching to any AMPS service provider system. Emergency calls made from the mobile phone **160** always go with the best service provider system available, regardless of carrier preference.

In one embodiment, the preferred roaming list (not shown) can contain up to 30 or 40 service provider systems. In another embodiment, the system determinator **128** of the system **100** can receive an updated preferred roaming list using data signals received from the base station **210**. Unlike the programming option described above, this new preferred roaming data must be sent from the base station **210** each time the mobile phone **160** is initialized. In still another embodiment, the mobile phone **160** could use a most recently used (MRU) list to determine one of the most recently used service provider systems, as is known in the art.

FIG. 5 shows a flowchart **400** illustrating another embodiment of the present invention. The system **100** begins in step **350** after the mobile phone **160** has established that the total received power Rx is greater than the threshold C (see FIG. 4). From step **350**, the mobile phone **160** enters the idle state **224**, as depicted in and described with reference to FIG. 3. As is known in the art, while in the idle state **224**, the base station **210** sends paging and other overhead messages to the mobile phone **160**. Step **402** illustrates that the mobile phone **160** is in the idle state **224**. In comparison **404**, the mobile phone **160** monitors signal levels for one or more predetermined conditions. The first condition the mobile phone **160** determines in comparison **404** is whether the CDMA pilot strength (*Ec/Io*) is less than a threshold A. The second condition

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the mobile phone **160** checks for is whether the pilot received power (RSSI) is less than a second threshold *B*.

The mobile phone **160** monitors the strength of the pilot channel at all times while operating in a particular cell. The pilot strength processor **120** of FIG. 1 performs the calculation within comparison **404**. As stated above, the pilot strength (*Ec/Io*) is dependent upon the number of cell phones **160** currently active within the given cell. That is, as the number of cell phones **160** active in the given cell increases, the pilot strength *Ec/Io* decreases.

The other condition measured in the step **404** is whether the pilot received power RSSI is less than the second threshold *B*. Recall that RSSI is independent of how many cell phones **160** are active in the given cell. Variation in the RSSI is indicative of path loss changes in the forward link from the base station **210** to the particular mobile phone **160**.

Note that the condition considered in comparison **404** consists of two independent measurements coupled by an AND clause. If either of the conditions yields a positive result (*i.e.*, if the pilot strength *Ec/Io* ever reaches or goes above the threshold *A* or if the RSSI ever reaches or goes above the threshold *B*), the result of comparison **404** is NO. In that event, in step **406**, the timer t2, controlled by the timers **118** of FIG. 1, is disabled and reset. The system **100** then returns to state **402** and comparison **404** where the pilot strength (*Ec/Io*) and the RSSI are both measured again. If, however, both the pilot strength (*Ec/Io*) and the RSSI are below their respective thresholds, the result of comparison **404** is YES. In that event, the system **100** moves to decision **408**.

In decision **408**, the system **100** determines whether the timer t2 is running by communicating with the timers **118**. If the timer t2 is not already running, the system **100** proceeds to step **410** and starts the timer t2 in the timers **118** of FIG. 1. The system **100** then returns to comparison **404** where the conditions are checked once again.

If the timer t2 has already started, the result of decision **408** is YES and, in decision **412** the system **100** determines whether or not the timer t2 has expired. If the timer t2 has not expired, the result of decision **412** is NO and the system **100** returns to comparison **404** where the conditions are once again

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checked. In an exemplary embodiment, the timer t2 is set to expire eight seconds after it starts.

Operation of the timer t2 is similar to the operation of the timer t1 (see FIG. 4). However, one major difference between timer t2 and timer t1 is that the mobile phone **160** that is in the idle state (*i.e.*, running flowchart **400**) occasionally goes to sleep. When asleep, the flowchart **400** maintains its current position (*i.e.*, whatever step the flowchart **400** is performing when it enters the sleep state will be suspended and will resume once it wakes up). The same applies to the timer t2, in that the timer is suspended at times during which the mobile phone **160** is asleep. Stated another way, when the mobile phone **160** goes to sleep, so does the timer t2. When the mobile phone **160** wakes up, it will either proceed eventually back to comparison **404**, or to step **414** as described below. If the system **100** returns to comparison **404**, the pilot strength (Ec/Io) and RSSI are again evaluated to see whether they exceed the thresholds A and B, respectively. If both conditions of decision **404** are met for the duration of timer t2, the system **100** will exit decision **412** as YES and attempt to acquire a new service provider system. That is, if the pilot strength and the RSSI are both less than the thresholds A and B, respectively, for the entire time period of timer t2 (*e.g.*, eight seconds), the system **100** will exit decision **412** as YES and attempt to acquire a more desirable service provider system in step **414**.

The step **414** is an improvement over the step **314**, as shown in and described with reference to FIG. 4. In step **414**, the phone can get the exact list of systems available in the area from the overhead messages transmitted by some BTS **210**. This BTS is the BTS which it is listening to during idle operation. This is better than counting on the roaming list, which can contain identifiers for a great many systems, and which therefore can take a long time before it finds the next preferred system.

It is to be understood that even though various embodiments and advantages of the present invention have been set forth in the foregoing description, the above disclosure is illustrative only, and changes may be made in detail, yet remain within the broad principles of the invention. For example, other quantitative measures, such as bit-error rate (BER), or the like can be used to determine the quality of the received signal. In addition, the time periods

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illustrated herein can be readily altered to accommodate different systems and different measurement criteria. For example, the system **100** can use one set of time periods when measuring signal quality in a digital system and a different set of time periods when measuring signal quality in an AMPS system. Therefore, the present invention is to be limited only by the appended claims.

We claim:

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CLAIMS

1. In a wireless communication system having more than one service provider system, a method to enhance performance of a mobile phone, comprising:

monitoring a level of performance of the mobile phone that has established communication with a first service provider system to determine a first performance level;

comparing the first performance level with a first threshold level; and

if the first performance level remains below the first threshold level for a selected duration of time, selecting a second service provider system and switching the mobile phone from the first service provider system to the second service provider system.

2. The method of claim 1 wherein the monitoring begins during an initialization stage of the mobile phone.

3. The method of claim 1 wherein the second service provider system is selected from a list of alternate service providers programmed into the mobile phone.

4. The method of claim 3 wherein the switching comprises:

disconnecting the mobile phone from the first service provider system; and

connecting the mobile phone to the second service provider network operating at the frequency retrieved from the list of alternate service providers.

5. The method of claim 1 wherein the performance monitored is total power received by the mobile phone.

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6. The method of claim 1 wherein the first service provider system is a CDMA digital cellular or PCS network and wherein the second service provider system is an AMPS cellular network.

7. The method of claim 1 wherein the mobile phone is a dual-mode or dual-band wireless telephone.

8. The method of claim 7 wherein the first service provider system and the second service provider system are owned by the same carrier.

9. In a wireless telephone communication system having more than one service provider system, a method to enhance performance of a mobile phone, comprising:

when the mobile phone that is communicating with a first service provider system is in an idle mode, monitoring a first performance level and a second performance level;

if the first performance level falls below a first threshold and the second performance level falls below a second threshold, starting a timer;

if, while the timer is running, either the first or second performance levels exceed their respective thresholds, resetting the timer and continue monitoring the first and second performance levels; and

if the timer exceeds a predetermined duration, switching the mobile telephone from the first service provider system to a second service provider system.

10. The wireless communication system of claim 9 wherein the first performance level is pilot strength.

11. The method of claim 9 wherein the second performance level is a received signal strength indication.

12. The method of claim 9 wherein both the first and second service provider systems are CDMA digital service provider systems.

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13. The method of claim 9 wherein the first service provider system is a CDMA digital service provider system and wherein the second service provider system is an AMPS cellular service provider system.

14. The method of claim 9 wherein the switching comprises:

retrieving a frequency from a list of alternate service provider systems;

disconnecting the mobile phone from the first service provider system; and

connecting the mobile phone to the second service provider system operating at the frequency retrieved from the list of alternate service provider systems.

15. The method of claim 14 wherein the list of alternate service provider systems is stored within the mobile phone.

16. A wireless telephone comprising:

a signal detector structured to receive and measure a first performance level of communication signals after the telephone has connected to a first service provider system;

a signal comparator structured to compare the first performance level with a first threshold level;

a timer that begins when the first performance level is below the first threshold level and expires a preselected time period after it begins; and

a system determinator structured to determine a second service provider system for the wireless telephone to connect to when the timer expires.

17. The wireless telephone of claim 16 wherein the signal detector detects total power received by the wireless telephone.

18. The wireless telephone of claim 16 wherein the first service provider system is a CDMA digital service provider system and the first

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threshold level used by the signal comparator is -107 dBm for cellular and –105 dBm for PCS.

19. The wireless telephone of claim 16 wherein the timer expires 2 seconds after it begins.

20. The wireless telephone of claim 16, further comprising a preferred roaming list containing operational frequencies of a plurality of possible service provider systems, the system determinator selecting an operational frequency of the second service provider system from the preferred roaming list and disconnecting the wireless telephone from the first service provider system and connecting the wireless telephone to the second service provider system operating at the frequency selected from the preferred roaming list.

21. The wireless telephone of claim 20 wherein the wireless preferred roaming list is stored within the wireless telephone.

22. The wireless telephone of claim 16 wherein the wireless telephone is a dual-mode or dual-band telephone.

23. The wireless telephone of claim 16, further comprising:

a second signal detector structured to receive and measure a second performance level of communication signals;

a second signal comparator structured to compare the second performance level with a second threshold level; and

wherein the timer begins when both the first performance level is below the first threshold level and when the second performance level is below the second threshold level.

24. The wireless telephone of claim 16 wherein the signal detector measures pilot strength.

25. The wireless telephone of claim 23 wherein the second signal detector measures pilot received power.

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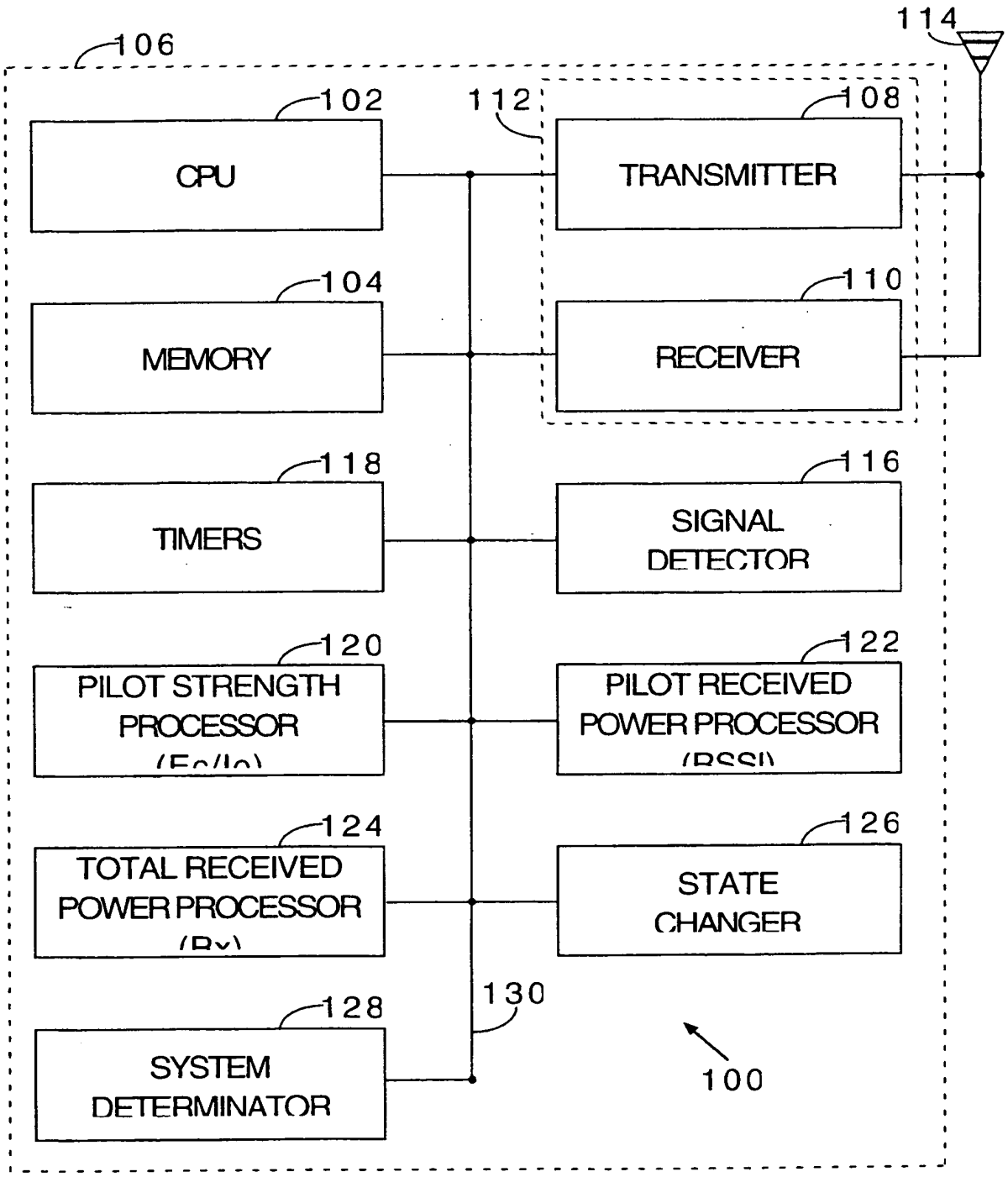

FIG. 1

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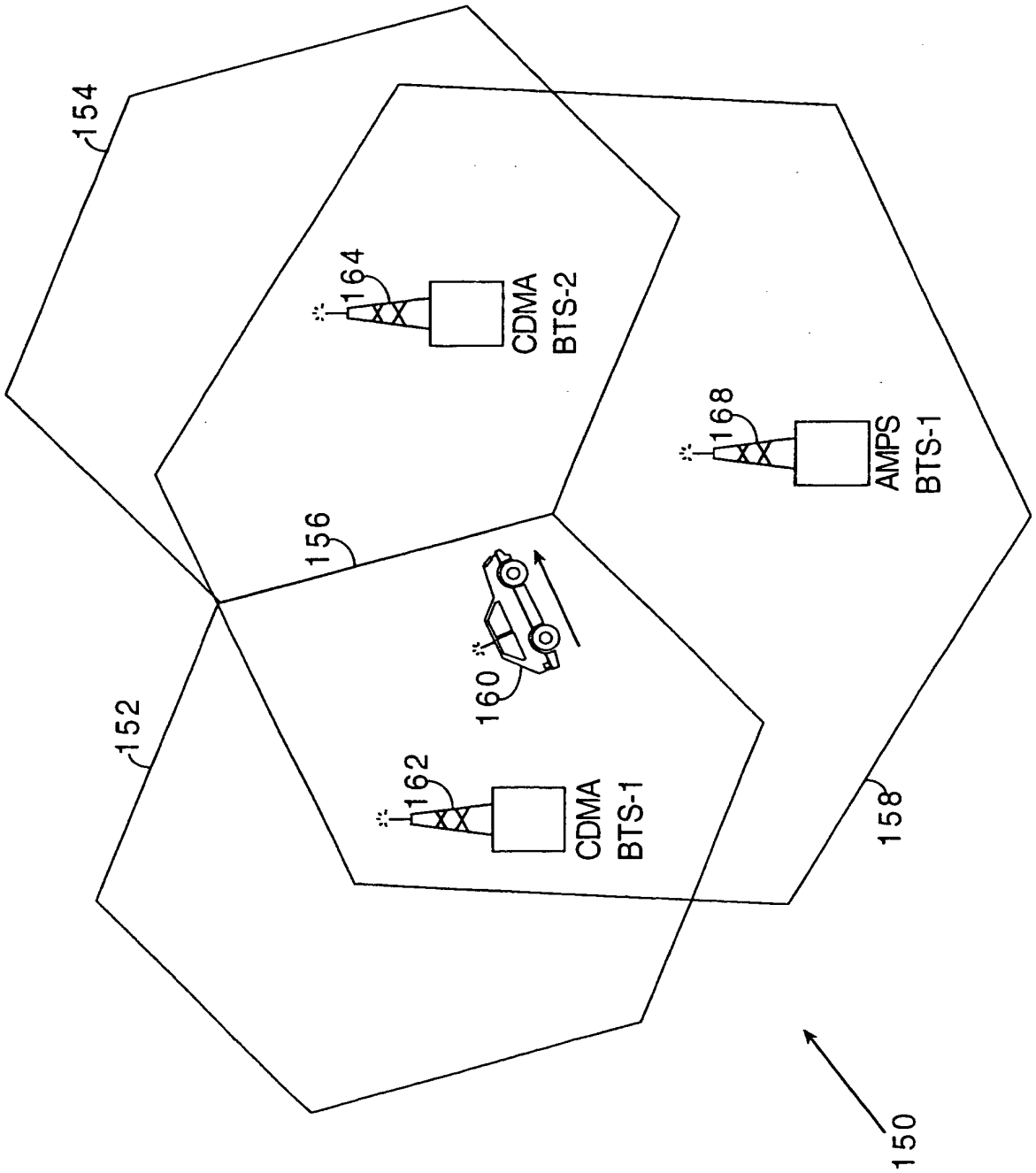

FIG. 2

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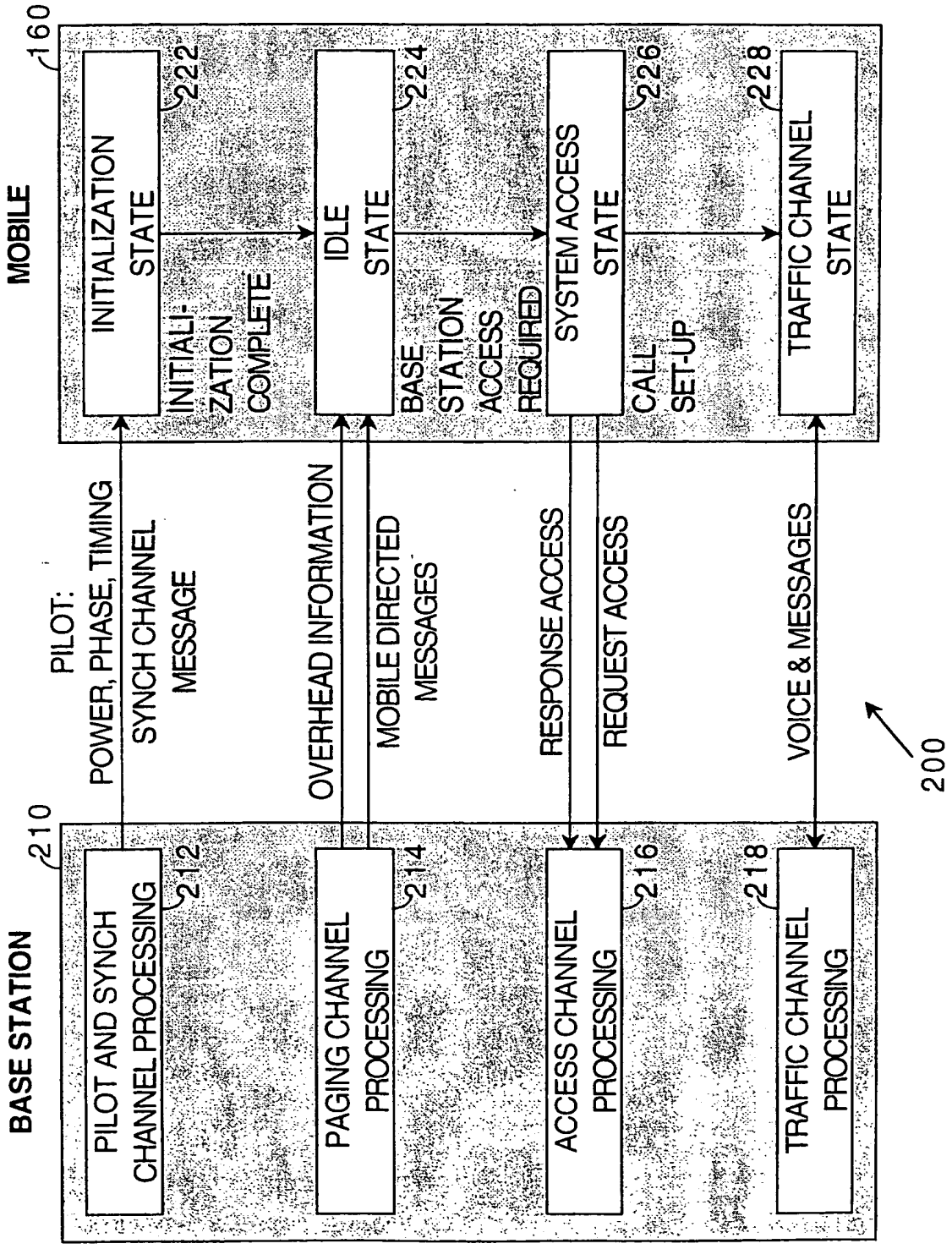

FIG. 3

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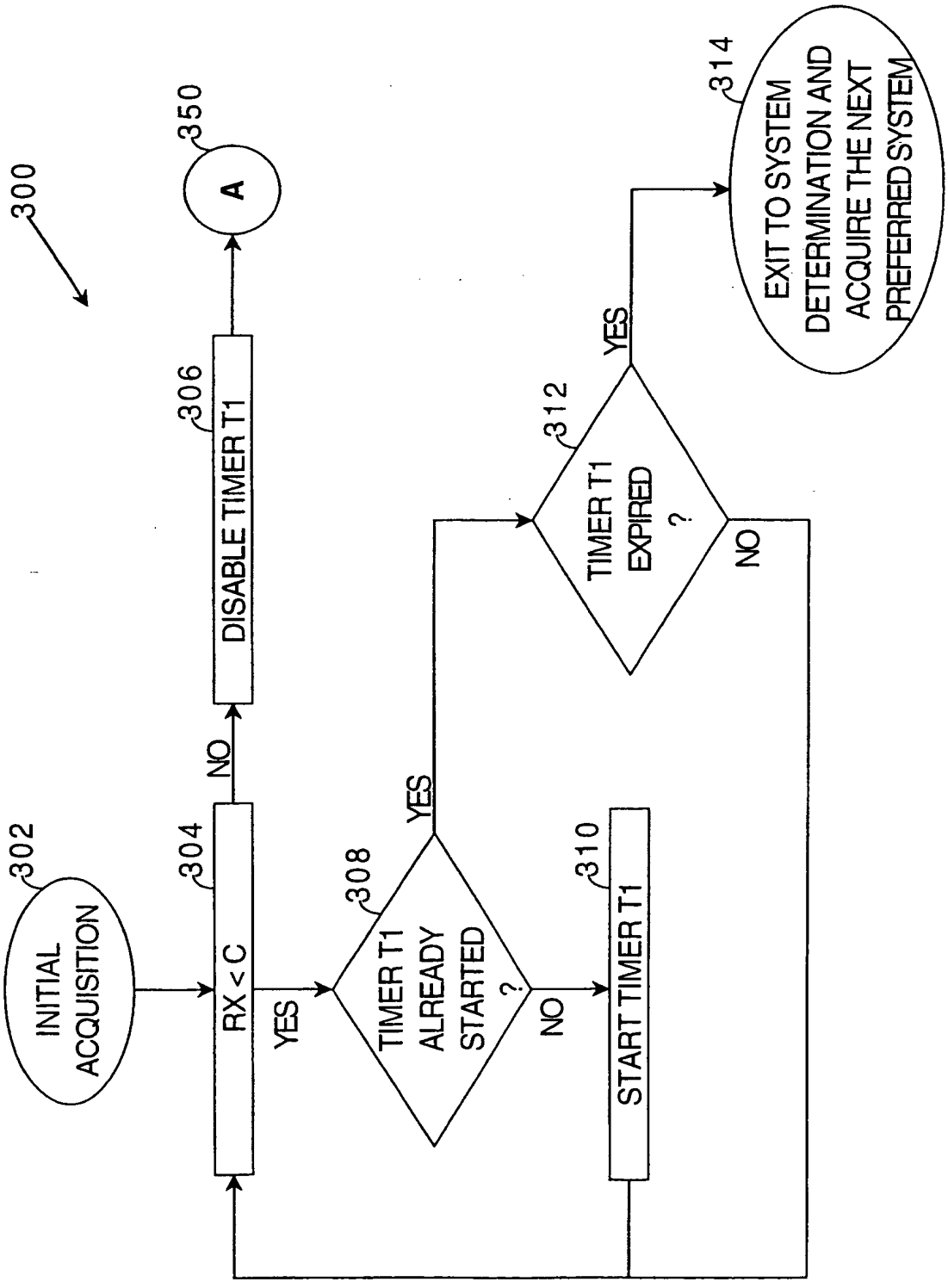

FIG. 4

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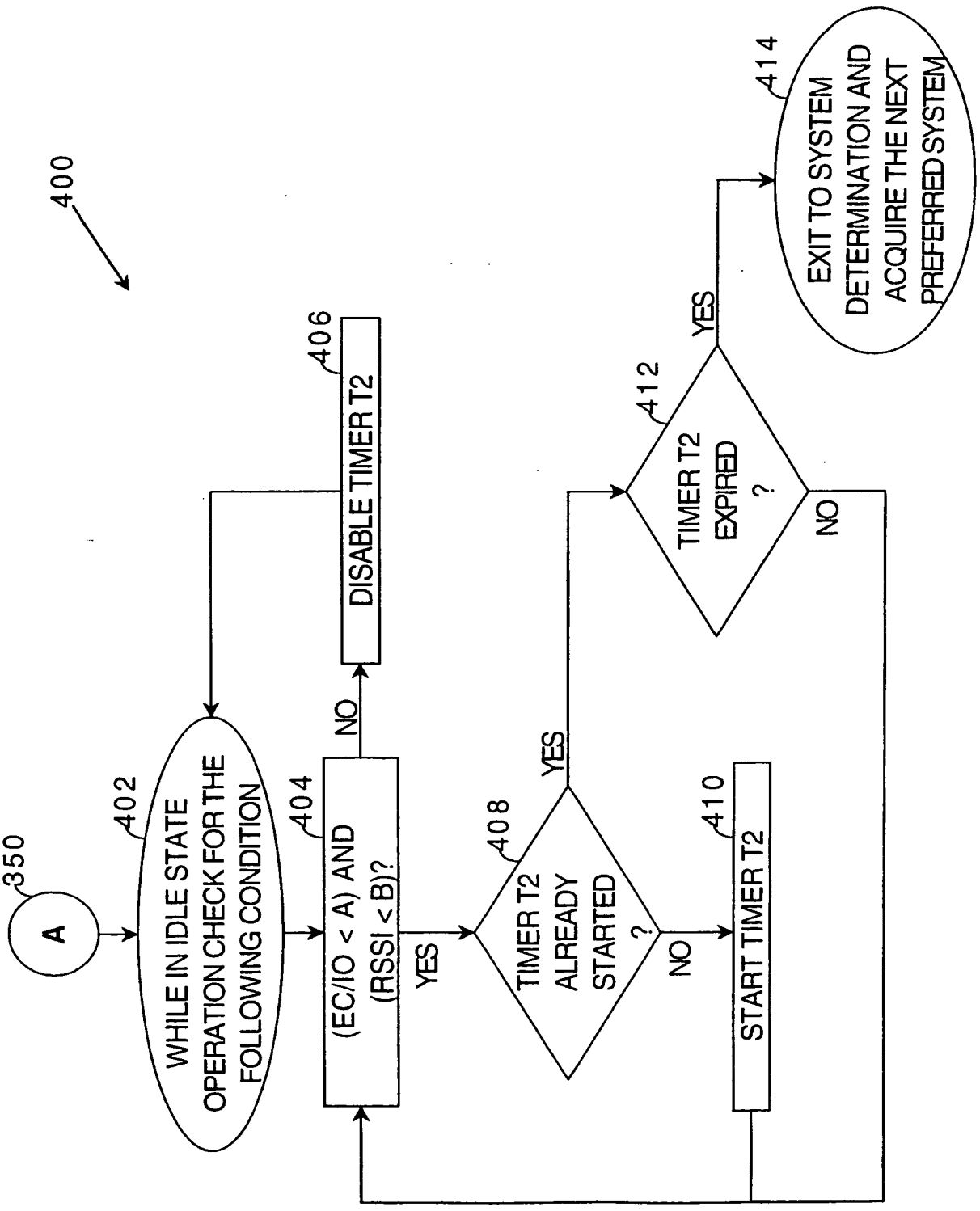

FIG. 5

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INTERNATIONAL SEARCH REPORT

Inte ional Application No
PCT/US 00/18599

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04Q7/38

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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Date of the actual completion of the international search	Date of mailing of the international search report
10 October 2000	20/10/2000

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Form PCT/ISA/210 (second sheet) (July 1992)

BNSDOCID: <WO___0103464A1_I_>

INTERNATIONAL SEARCH REPORT

Int ional Application No
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BNSDOCID: <WO___0103464A1_I_>

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

CORRECTED VERSION

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
11 January 2001 (11.01.2001)

PCT

(10) International Publication Number
WO 01/003464 A1

(51) International Patent Classification[7]: H04Q 7/38

(21) International Application Number: PCT/US00/18599

(22) International Filing Date: 6 July 2000 (06.07.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
09/348,442 7 July 1999 (07.07.1999) US

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(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW.

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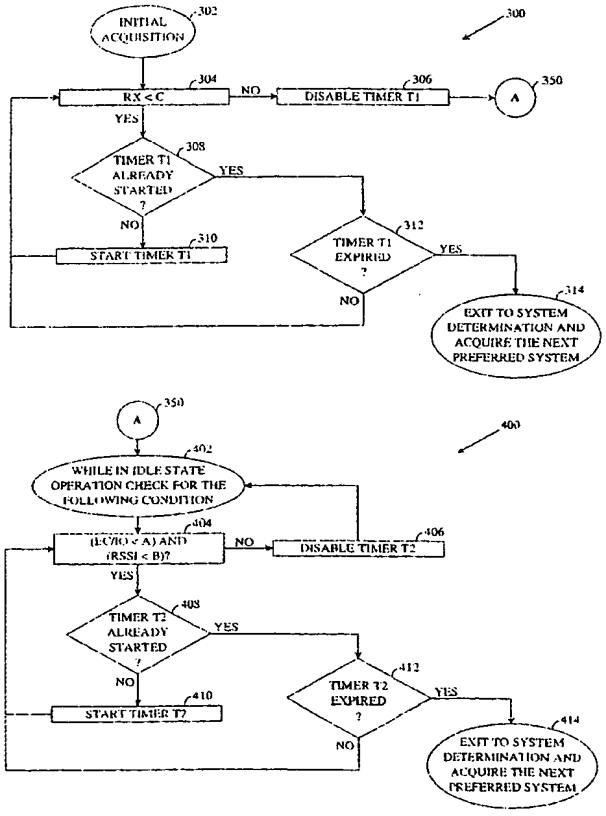
(54) Title: SYSTEM AND METHOD FOR EDGE OF COVERAGE DETECTION IN A WIRELESS COMMUNICATION DEVICE



(57) Abstract: A method to enhance performance of a dual-mode or dual-band mobile phone includes, after the phone has initially connected to a CDMA wireless network, monitoring (304) a level of total power received by the phone. This power level is compared (304) to a preset threshold level (C). If the power level remains below the threshold level for over two seconds (308, 312), the dual-mode or dual-band phone switches (314) to an AMPS or other network retrieved from the preferred roaming list that is stored in the phone. If the power level is above the threshold, the phone moves into the idle state (402). Once in the idle state, both the pilot strength and Received Signal Strength Indication are monitored (404). If both of these levels are below respective thresholds for over eight seconds (408, 412), the phone switches (414) to another network stored in the preferred roaming list. If the mobile phone is not a dual-mode or dual-band phone, the mobile phone can perform similar measurements and switch between service provider systems compatible with the mobile phone.

WO 01/003464 A1

(84) **Designated States** *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*

(48) **Date of publication of this corrected version:**
5 December 2002

(15) **Information about Correction:**
see PCT Gazette No. 49/2002 of 5 December 2002, Section II

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

BNSDOCID: <WO___0103464A1_IA>

SYSTEM AND METHOD FOR EDGE OF COVERAGE DETECTION IN A WIRELESS COMMUNICATION DEVICE

I. Field of the Invention

The present invention is related generally to a wireless communication device and, more particularly, to a system and method to detect the edge of service in a first communication system and obtain coverage in a second communication system for the wireless communication device.

II. Background of the Invention

Wireless communication devices, such as cellular telephones, are widely used as a replacement for and in addition to conventional telephone systems. In addition to providing the functionality of a conventional telephone, wireless communication devices offer the advantage of portability, thus enabling the user to establish a wireless communication link between virtually any two locations on Earth.

Wireless communication devices operate within regions or cells of coverage each having a geographic coverage area. A transmitter and receiver, centrally located within each cell, is controlled such that the effective coverage area of the cell just overlaps with adjacent cells. Cells for analog wireless communication devices and cells for digital wireless communication devices may not be coextensive. That is, although a given city may have complete analog cellular coverage and complete digital cellular coverage, analog and digital cell boundaries are usually different.

Typically, wireless communication devices have lower levels of performance when they are near the edge of a cell than when they are not near an edge. Therefore, when traveling from one cell to another, performance of a wireless communication device tends to degrade while approaching the edge of a first cell and does not return to full performance until the wireless communication device is away from the edge of the second cell. This is an especially important effect when the cell is on the edge of the coverage area, where there is no second cell to move into. This degradation is especially

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frustrating when the edge of one system's coverage area is the beginning of another system's coverage area. Thus, it is apparent that there is a need to increase the performance of wireless communication devices when located near the edge of a cell, and especially at the edge of a coverage area. The present invention provides this and other advantages as will be apparent from the following figures and accompanying description.

SUMMARY OF THE INVENTION

In one aspect of the present invention, a system and method to enhance performance of a mobile phone is presented. The method includes monitoring a level of performance of the mobile telephone communicating with a first service provider system, comparing the first performance level with a first threshold level and, if the first performance level remains below the first threshold level for a first duration of time, switching the telephone to a second service provider system.

In another aspect of the invention, when the mobile phone is in an idle mode, first and second performance levels are monitored. If the first performance level falls below a first threshold or the second performance level falls below a second threshold a timer is started. If both the first and second performance levels exceed their respective thresholds, the timer is reset, but if the timer runs long enough to exceed a preset time limit, the mobile telephone switches to another service provider system. If the mobile phone is a dual-mode or dual-band phone, it is possible to switch between modes or bands when switching service provider systems.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a functional block diagram of an exemplary embodiment of the wireless communication device of the present invention.

FIG. 2 illustrates a representative coverage diagram for wireless communication systems.

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FIG. 3 is a flowchart indicating different states of a wireless communication device and a base station for a wireless communication device.

FIG. 4 is a flowchart showing the logical flow of an embodiment of the present invention.

FIG. 5 is a flowchart indicating logical flow for another embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention is directed to a technique for increasing the performance of a wireless communication device near the edge of coverage when another wireless system is available. Most populated areas of the United States and of the world are covered by at least one type of wireless communication service. One type of such service is Advanced Mobile Phone Service (AMPS). AMPS is an analog cellular phone system and is well known in the art. Additionally, some areas may have Personal Communication Service (PCS), or a digital cellular telephone system or both. One form of digital cellular telephone system is Code Division Multiple Access (CDMA), also well known in the art.

Several factors contribute to the performance of a wireless communication device, such as distance from the cellular base station transceiver subsystem (BTS), BTS transmitter power, geographical considerations, and proximity to buildings or other reflective surfaces among other factors. When the wireless communication device is traveling between cells, performance gradually degrades as the wireless communication device approaches the edge of the current cell and gradually increases once the wireless communication device establishes communication with the BTS of an adjacent cell and moves away from the boundary between the cells and closer to the BTS in the newly acquired cell. The process of switching communication from one cell to another is called a handoff. Many types of handoffs, such as hard and soft handoffs, are known in the art and need not be described in detail herein.

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Depending on the location of the cell boundaries, it may be the case that the wireless communication device is handing off between two CDMA cells (and thus experiencing poor quality while near the boundaries of the CDMA cells) while also located in the middle of an AMPS cell where the wireless communication device would be experiencing excellent service if the device were currently using AMPS.

Occasionally, CDMA systems may have a link imbalance where a forward link, (*i.e.*, the data link sent from the BTS to a wireless communication device such as a mobile or cell phone), is much stronger than the reverse link (*i.e.*, the data from the wireless communication device back to the BTS). On these occasions, it is possible for the wireless communication device to receive paging messages from the BTS indicating CDMA coverage is available, even though the mobile phone is unable to communicate with the BTS over the reverse link at a sufficient level to make or receive a call. This can be frustrating for the operator of the mobile phone. It is also particularly frustrating to carriers that operate both CDMA and AMPS systems because the mobile phone may be in a location where it could receive good AMPS coverage. While a carrier that only operates CDMA systems may desire that the mobile phone stay with a CDMA system at all times, a carrier that operates both AMPS and CDMA systems prefers the mobile phone to connect to the better service when performance with the current system degrades. For instance, the mobile phone may switch from CDMA to AMPS when performance is deficient in the CDMA system but would be adequate in the AMPS system. The present invention allows the wireless communication device to determine it is in a weak coverage area and try other systems in order to establish better service.

The present invention is embodied in a system **100** illustrated in the functional block diagram of FIG. 1. The system **100** includes a central processing unit (CPU) **102** which controls operation of the system. A memory **104**, which may include both read-only memory (ROM) and random access memory (RAM), provides instructions and data to the CPU **102**. A portion of the memory **104** may also include non-volatile random access memory (NVRAM).

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The system **100**, which is typically embodied in a wireless communication device such as a cellular telephone, also includes a housing **106** that contains a transmitter **108** and a receiver **110** to allow transmission and reception of data, such as audio communications, between the system **100** and a remote location, such as a cell site controller or BTS (see FIG. 2). The transmitter **108** and receiver **110** may be combined into a transceiver **112**. An antenna **114** is attached to the housing **106** and electrically coupled to the transceiver **112**. The operation of the transmitter **108**, receiver **110**, and antenna **114** is well known in the art and need not be described herein.

The system **100** also includes a signal detector **116** used to detect and quantify the level of signals received by the transceiver **112**. The signal detector **116** detects such signals as total energy, pilot energy per pseudonoise (PN) chips, power spectral density, and other signals, as is known in the art. Various indicators and values are calculated by the signal detector **116** for use in the system **100**, as described in further detail below.

A set of timers **118** works in conjunction with a pilot strength processor **120**, a pilot received power processor **122**, and a total received power processor **124**. By measuring the levels of the signals received and processing these signals, the system **100** can determine the quality of the communication channel between the wireless communication device and its BTS.

The pilot strength processor **120** receives a pilot strength indicator (*Ec/Io*) from the signal detector **116**. The signal detector **116** divides the ratio of pilot energy per PN chip (*Ec*) by the total power spectral density received at the transceiver **112** (*Io*). This ratio of pilot energy to overall received energy is called "pilot strength," as is known in the art. Also as known in the art, the pilot strength depends on loading conditions of an active cell and adjacent cells, and thus is an indication of traffic load in a particular cell.

The total received power processor **124** uses a variable *Rx* that is detected and quantified at the signal detector **116**. The total received power (*Rx*) is a measure of all power received at the transceiver **112**. It includes thermal noise, interference from other callers and a pilot signal transmitted to that particular transceiver **112**. A total of all this energy received is stored in the variable *Rx* indicating total received power.

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The pilot received power processor **122** receives a Received Signal Strength Indicator (RSSI) from the signal detector **116**. The RSSI indicates the pilot received power and, in an exemplary embodiment, is calculated by adding the total received power (*Rx*) with the (*Ec/Io*), as is known in the art. The RSSI is independent of system loading and variation in the RSSI indicates forward link path loss changes. These path loss changes are important in determining when to switch service, described in detail below.

A state changer **126** of the system **100** controls the state of the wireless communication device based on a current state and additional signals received by the transceiver **112** and detected by the signal detector **116**. The wireless communication device is capable of operating in any one of a number of states, as later described with reference to FIG. 3.

The system **100** also includes a system determinator **128** used to control the wireless communication device and determine which service provider system the wireless communication device should transfer to when it determines the current service provider system is inadequate.

The various components of the system **100** are coupled together by a bus system **130** which may include a power bus, a control signal bus, and a status signal bus in addition to a data bus. However, for the sake of clarity, the various busses are illustrated in FIG. 1 as the bus system **130**. One skilled in the art will appreciate that the system **100** illustrated in FIG. 1 is a functional block diagram rather than a listing of specific components. For example, although the pilot strength processor **120**, pilot received power processor **122**, and the total received power processor **124** are illustrated as three separate blocks within the system **100**, they may in fact be embodied in one physical component, such as a digital signal processor (DSP). They may also reside as program codes in the memory **104** and operated on by the CPU **102**. The same considerations apply to the other components listed in system **100** of FIG. 1.

Operation of components shown in the system **100** of FIG. 1 will be explained with reference to FIGs. 2-5. FIG. 2 shows a coverage diagram **150** including multiple boundaries of wireless communication cells. FIG. 2 is not drawn to scale, but is merely intended to illustrate areas of coverage and boundaries between those areas of coverage. The diagram **150** includes a first

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CDMA cell **152** that shares a common boundary **156** with an adjacent CDMA cell **154**. Although the boundary **156** is illustrated as a straight line between the CDMA cell **152** and the CDMA cell **154**, it is well understood that the areas of coverage in the CDMA cells overlap and that the boundary **156** depends on many factors, such as geographic terrain, buildings, and the like. For the sake of clarity in understanding the present invention, the boundary **156** in FIG. 2 is shown as a straight line.

The CDMA cell **152** contains a BTS **162** labeled CDMA BTS-1. The BTS **162** is located in approximately the center of the CDMA cell **152**. The CDMA cell **154** likewise contains a BTS **164** located roughly in the center of that CDMA cell **154** and labeled CDMA BTS-2. As stated above, some of the factors that determine the distance of the borders of the cells **152, 154** from their respective BTS' include antenna shape and orientation, terrain, presence or absence of reflective surfaces, and environmental factors such as weather.

An AMPS cell **158** is shown having noncontiguous borders with the CDMA cells **152** and **154**. The size of the cells **152, 154**, and **158** does not indicate actual relative size, or orientation, but is shown only for illustration. As is known in the art, CDMA cells are typically smaller than AMPS cells, but this is not relevant for purposes of explanation of the invention as the invention will operate in cells of any size and orientation.

The AMPS cell **158** includes a BTS **168** in its approximate center, labeled AMPS BTS-1. The AMPS BTS **168** differs from the CDMA BTSs **162** and **164** principally in the frequencies transmitted and received as well as the modulation format. The AMPS BTS **168** transmits and receives an analog signal on a first set of frequencies while the CDMA BTSs **162** and **164** transmit and receive digital signals on a separate set of frequencies. These and other differences between the AMPS system and a digital system, such as CDMA, are well known in the art and need not be described herein.

In FIG 2, a wireless communication device such as a mobile or mobile phone **160** is depicted as being transported by an automobile in CDMA cell **152**. The mobile phone **160** is approaching the border **156**. As described above, the quality of the wireless communication between the mobile phone **160** and the BTS **162** degrades at the edge of the CDMA cell **152**. Although CDMA

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technology includes error correction to make up for some data lost in transmission, occasionally the quality of service degrades to the point that communication is impossible.

In some markets, the same carrier, for instance, AT&T or Ameritech will own both the CDMA systems and the AMPS systems for a given geographical area. Although most mobile phones originally produced for the AMPS system are not capable of communicating with a CDMA system, the reverse is not always true. Specifically, many mobile phones can communicate with both the CDMA and AMPS BTSs. These phones are known as dual-mode phones. CDMA systems operate in two frequency bands, the cellular band (800 MHz) and the PCS band (1900 MHz). AMPS systems also operate in the 800 MHz band. A PCS phone which also operates in the 800 MHz band, whether in cellular mode or AMPS mode, is known as a dual-band phone.

If the same carrier owns both an AMPS system and a CDMA system within the same geographical area, the carrier wants to provide the best service to the mobile phone **160** irrespective of which system (AMPS or CDMA) on which the phone is currently operating. For instance, when the mobile phone **160** is nearing the edge of a CDMA system, the system **100** can search for the best available system, regardless of type. This is a radical change from previous cell phone systems that required the mobile phone **160** to stay on one system regardless of quality because that was all that was available.

As depicted in FIG. 2, the mobile phone **160** is nearing the border **156**. It is likely experiencing a poor connection either from the BTS **162** or as it is establishing a new connection with BTS **164**. However, note that the AMPS BTS station **168**, given its proximity to the mobile phone **160**, is likely able to provide a good level of service. Unfortunately, conventional cell phones are designed to remain with one system as long as one is available. In this example, a cell phone of the prior art will stay with the CDMA system, communicating with the BTSs **162** and **164** regardless of how poor the signal becomes. As described below, embodiments of the present invention are able to measure factors indicative of poor cellular communication quality, and if the mobile phone **160** is experiencing poor quality, search for another cellular system as directed by the carrier.

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In FIG. 3, a state diagram **200** shows different operational states for a base station **210** and the mobile phone **160**. These states are known in the art and will be discussed only briefly. In an initialization state **222**, the mobile phone **160** receives a pilot signal and synchronization signals from the base station **210**, which is in a pilot and sync channel processing state **212**. Once the mobile phone **160** is initialized, it enters an idle state **224**. While the mobile phone **160** is in the idle state **224**, the base station **210** is in a paging channel processing state **214** and sends paging messages and overhead information to the mobile phone. That is, the mobile phone **160** monitors and processes Paging Channel messages and overhead information sent by the base station. The mobile phone **160** remains in the idle state **224** once it has powered up and initialized while it is waiting to place a call, or waiting for a call to be placed to it. When the mobile phone **160** makes or receives a call, it changes from the idle state **224** to a system access state **226**. In the system access state **226**, the mobile phone **160** requests a channel from the base station **210**. The base station **210** responds to set up the channel in an access channel processing state **216**. Once the traffic channel is set up between the base station **210** and the mobile phone **160**, the mobile phone enters a traffic channel state **228**, while the base station **210** enters a traffic channel processing state **218**. While in these states, the mobile phone **160** is sending and receiving data, such as voice data to and from the base station **210**.

Embodiments of the invention are directed to two main systems maintained in the mobile phone **160**. In the first embodiment, described with reference to FIG. 4 and related text, the mobile phone **160** is just entering a service provider system. This can occur when the mobile phone **160** is first turned on, or is first attempting to communicate with a BTS. The mobile phone **160** first determines whether it is receiving sufficient total power to permit a satisfactory level of performance by the cell phone. If so, the mobile phone **160** enters the idle state **224** for further monitoring. If not enough total power is reaching the mobile phone **160**, it exits the first service provider system to find a better service provider system. In the second embodiment, while in the idle state **224**, the mobile phone **160** monitors the pilot strength (*Ec/Io*) and the pilot received power (RSSI) to determine if both are below their respective

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predetermined thresholds. If both of these levels remain below the respective thresholds too long, the mobile phone **160** searches for another service provider system. This second embodiment is described with respect to FIG. 5 and the related text.

A flowchart **300** of FIG. 4 is performed while the mobile phone **160** is in the initialization state **222** (see FIG. 3). The flowchart **300** begins with an initial acquisition **302**. The mobile phone **160** will be in the initial acquisition **302** if the phone just acquired a CDMA service provider system, for instance, if the mobile phone **160** was just turned on, reset, or just changed from another service provider system. In the initial acquisition step **302**, the mobile phone **160** is primarily interested in knowing how much total received power (*Rx*) is present. It determines this information using the total received power processor **124** (see FIG. 1).

After the mobile phone **160** has acquired a CDMA service provider system in the initial acquisition **302**, the mobile phone compares the total received power *Rx*, to a threshold *C* in a comparison step **304**. This comparison is performed by the total received power processor **124** of FIG. 1. In an exemplary embodiment, total received power is measured in dBm, and includes CDMA signals, noise, and interference. CDMA signals are those signals sent from the base station **210** (see FIG. 3) directed to the particular mobile phone **160**. Interference is the sum of signals being transmitted from any base station **210** or from any other mobile phones **160** that is received by the transceiver **112** (see FIG. 1) and quantified by the signal detector **116**. Noise is any other signal detected at the transceiver **112** and can include environmental noise and/or disruptions in the electromagnetic spectrum.

In comparison **304** of FIG. 4, the total received power processor **124** determines whether or not the total received power *Rx* is less than the threshold *C*. The threshold *C* can be any appropriate value, and by way of example, is set at -105 dBm for CDMA PCS and -107 dBm for CDMA cellular systems. If the total received power processor **124** determines that *Rx* is greater than *C*, the output from comparison **304** is NO and the system **100** progresses to step **306** where a timer t1 is disabled. The timer t1 is located within the timers **118** of FIG. 1. In this particular instance, where the total received power in

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comparison **304** is initially greater than *C*, the timer t1 never starts. Regardless of whether the timer t1 was ever running, once the timer t1 is disabled in step **306**, the system **100** progresses to an initial step **350** depicted in FIG. 5.

Returning to comparison **304**, if the total received power *Rx* is less than *C*, the result of comparison **304** is YES and the system **100** enters a decision **308**. In decision **308**, a query is sent to the timers **118** of FIG. 1 to determine if the timer t1 had been previously started. If the timer t1 had not already been started, it is then immediately started in step **310**, and the system **100** loops back to the comparison **304**, where the total received power *Rx* is again checked against the threshold *C*.

If by this time the total received power *Rx* is above the threshold *C*, the system **100** exits comparison **304** with a NO response, as described above. However, if the total received power *Rx* remains below the threshold *C* in comparison **304**, the system **100** again enters decision **308**. Since the timer t1 is already running, the system **100** checks to see if the timer t1 has expired in decision **312**. In an exemplary embodiment, the timer t1 will expire two seconds after it starts. If the timer t1 has not yet expired, the result of decision **312** is NO and the system **100** loops back to comparison **304** where the total received power *Rx* is again checked against the threshold *C*.

As an overview to the flowchart **300**, once the mobile phone **160** enters the initial acquisition state **302**, the total received power processor **124** evaluates the total received power *Rx* signal. If at any time within the time period of the timer t1 (*e.g.*, two seconds), the total received power *Rx* climbs above the threshold *C*, the system **100** exits to step **350**, shown in FIG. 5. If, however, the total received power *Rx* is below the threshold *C*, for more than two seconds, the system **100** exits to step **314**, described below.

In step **314**, the system **100** forces the mobile phone **160** to abandon the present service provider system to try to connect to a better one. This system determination is performed by the system determinator **128** of FIG. 1. This system determination can be performed in a number of ways. For instance, in an exemplary embodiment, a list of preferred service provider systems is kept in a preferred roaming list (not shown). The preferred roaming list is a list of frequencies and bands used in different parts of the country. A

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telephone manufacturer will originally program the system determinator **128** with a generic preferred roaming list, containing default frequencies within the frequency tables. When the mobile phone **160** is purchased by a customer, the carrier servicing the mobile phone **160** may reprogram the preferred roaming list for the benefit of the carrier. For example, the carrier could program the preferred roaming list to attempt to contact their own service provider systems first, and then contact all the service provider systems with whom they have contracts, and then try any available service provider system. Alternatively, the carrier may program the preferred roaming list to try all of the CDMA service provider systems prior to switching to any AMPS service provider system. Emergency calls made from the mobile phone **160** always go with the best service provider system available, regardless of carrier preference.

In one embodiment, the preferred roaming list (not shown) can contain up to 30 or 40 service provider systems. In another embodiment, the system determinator **128** of the system **100** can receive an updated preferred roaming list using data signals received from the base station **210**. Unlike the programming option described above, this new preferred roaming data must be sent from the base station **210** each time the mobile phone **160** is initialized. In still another embodiment, the mobile phone **160** could use a most recently used (MRU) list to determine one of the most recently used service provider systems, as is known in the art.

FIG. 5 shows a flowchart **400** illustrating another embodiment of the present invention. The system **100** begins in step **350** after the mobile phone **160** has established that the total received power Rx is greater than the threshold C (see FIG. 4). From step **350**, the mobile phone **160** enters the idle state **224**, as depicted in and described with reference to FIG. 3. As is known in the art, while in the idle state **224**, the base station **210** sends paging and other overhead messages to the mobile phone **160**. Step **402** illustrates that the mobile phone **160** is in the idle state **224**. In comparison **404**, the mobile phone **160** monitors signal levels for one or more predetermined conditions. The first condition the mobile phone **160** determines in comparison **404** is whether the CDMA pilot strength (*Ec/Io*) is less than a threshold A. The second condition

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the mobile phone **160** checks for is whether the pilot received power (RSSI) is less than a second threshold *B*.

The mobile phone **160** monitors the strength of the pilot channel at all times while operating in a particular cell. The pilot strength processor **120** of FIG. 1 performs the calculation within comparison **404**. As stated above, the pilot strength (*Ec/Io*) is dependent upon the number of cell phones **160** currently active within the given cell. That is, as the number of cell phones **160** active in the given cell increases, the pilot strength *Ec/Io* decreases.

The other condition measured in the step **404** is whether the pilot received power RSSI is less than the second threshold *B*. Recall that RSSI is independent of how many cell phones **160** are active in the given cell. Variation in the RSSI is indicative of path loss changes in the forward link from the base station **210** to the particular mobile phone **160**.

Note that the condition considered in comparison **404** consists of two independent measurements coupled by an AND clause. If either of the conditions yields a positive result (*i.e.*, if the pilot strength *Ec/Io* ever reaches or goes above the threshold *A* or if the RSSI ever reaches or goes above the threshold *B*), the result of comparison **404** is NO. In that event, in step **406**, the timer t2, controlled by the timers **118** of FIG. 1, is disabled and reset. The system **100** then returns to state **402** and comparison **404** where the pilot strength (*Ec/Io*) and the RSSI are both measured again. If, however, both the pilot strength (*Ec/Io*) and the RSSI are below their respective thresholds, the result of comparison **404** is YES. In that event, the system **100** moves to decision **408**.

In decision **408**, the system **100** determines whether the timer t2 is running by communicating with the timers **118**. If the timer t2 is not already running, the system **100** proceeds to step **410** and starts the timer t2 in the timers **118** of FIG. 1. The system **100** then returns to comparison **404** where the conditions are checked once again.

If the timer t2 has already started, the result of decision **408** is YES and, in decision **412** the system **100** determines whether or not the timer t2 has expired. If the timer t2 has not expired, the result of decision **412** is NO and the system **100** returns to comparison **404** where the conditions are once again

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checked. In an exemplary embodiment, the timer t2 is set to expire eight seconds after it starts.

Operation of the timer t2 is similar to the operation of the timer t1 (see FIG. 4). However, one major difference between timer t2 and timer t1 is that the mobile phone **160** that is in the idle state (*i.e.*, running flowchart **400**) occasionally goes to sleep. When asleep, the flowchart **400** maintains its current position (*i.e.*, whatever step the flowchart **400** is performing when it enters the sleep state will be suspended and will resume once it wakes up). The same applies to the timer t2, in that the timer is suspended at times during which the mobile phone **160** is asleep. Stated another way, when the mobile phone **160** goes to sleep, so does the timer t2. When the mobile phone **160** wakes up, it will either proceed eventually back to comparison **404**, or to step **414** as described below. If the system **100** returns to comparison **404**, the pilot strength (Ec/Io) and RSSI are again evaluated to see whether they exceed the thresholds A and B, respectively. If both conditions of decision **404** are met for the duration of timer t2, the system **100** will exit decision **412** as YES and attempt to acquire a new service provider system. That is, if the pilot strength and the RSSI are both less than the thresholds A and B, respectively, for the entire time period of timer t2 (*e.g.*, eight seconds), the system **100** will exit decision **412** as YES and attempt to acquire a more desirable service provider system in step **414**.

The step **414** is an improvement over the step **314**, as shown in and described with reference to FIG. 4. In step **414**, the phone can get the exact list of systems available in the area from the overhead messages transmitted by some BTS **210**. This BTS is the BTS which it is listening to during idle operation. This is better than counting on the roaming list, which can contain identifiers for a great many systems, and which therefore can take a long time before it finds the next preferred system.

It is to be understood that even though various embodiments and advantages of the present invention have been set forth in the foregoing description, the above disclosure is illustrative only, and changes may be made in detail, yet remain within the broad principles of the invention. For example, other quantitative measures, such as bit-error rate (BER), or the like can be used to determine the quality of the received signal. In addition, the time periods

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illustrated herein can be readily altered to accommodate different systems and different measurement criteria. For example, the system **100** can use one set of time periods when measuring signal quality in a digital system and a different set of time periods when measuring signal quality in an AMPS system. Therefore, the present invention is to be limited only by the appended claims.

We claim:

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CLAIMS

1. In a wireless communication system having more than one service provider system, a method to enhance performance of a mobile phone, comprising:

monitoring a level of performance of the mobile phone that has established communication with a first service provider system to determine a first performance level;

comparing the first performance level with a first threshold level; and

if the first performance level remains below the first threshold level for a selected duration of time, selecting a second service provider system and switching the mobile phone from the first service provider system to the second service provider system.

2. The method of claim 1 wherein the monitoring begins during an initialization stage of the mobile phone.

3. The method of claim 1 wherein the second service provider system is selected from a list of alternate service providers programmed into the mobile phone.

4. The method of claim 3 wherein the switching comprises:

disconnecting the mobile phone from the first service provider system; and

connecting the mobile phone to the second service provider network operating at the frequency retrieved from the list of alternate service providers.

5. The method of claim 1 wherein the performance monitored is total power received by the mobile phone.

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6. The method of claim 1 wherein the first service provider system is a CDMA digital cellular or PCS network and wherein the second service provider system is an AMPS cellular network.

7. The method of claim 1 wherein the mobile phone is a dual-mode or dual-band wireless telephone.

8. The method of claim 7 wherein the first service provider system and the second service provider system are owned by the same carrier.

9. In a wireless telephone communication system having more than one service provider system, a method to enhance performance of a mobile phone, comprising:

when the mobile phone that is communicating with a first service provider system is in an idle mode, monitoring a first performance level and a second performance level;

if the first performance level falls below a first threshold and the second performance level falls below a second threshold, starting a timer;

if, while the timer is running, either the first or second performance levels exceed their respective thresholds, resetting the timer and continue monitoring the first and second performance levels; and

if the timer exceeds a predetermined duration, switching the mobile telephone from the first service provider system to a second service provider system.

10. The wireless communication system of claim 9 wherein the first performance level is pilot strength.

11. The method of claim 9 wherein the second performance level is a received signal strength indication.

12. The method of claim 9 wherein both the first and second service provider systems are CDMA digital service provider systems.

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13. The method of claim 9 wherein the first service provider system is a CDMA digital service provider system and wherein the second service provider system is an AMPS cellular service provider system.

14. The method of claim 9 wherein the switching comprises:

retrieving a frequency from a list of alternate service provider systems;

disconnecting the mobile phone from the first service provider system; and

connecting the mobile phone to the second service provider system operating at the frequency retrieved from the list of alternate service provider systems.

15. The method of claim 14 wherein the list of alternate service provider systems is stored within the mobile phone.

16. A wireless telephone comprising:

a signal detector structured to receive and measure a first performance level of communication signals after the telephone has connected to a first service provider system;

a signal comparator structured to compare the first performance level with a first threshold level;

a timer that begins when the first performance level is below the first threshold level and expires a preselected time period after it begins; and

a system determinator structured to determine a second service provider system for the wireless telephone to connect to when the timer expires.

17. The wireless telephone of claim 16 wherein the signal detector detects total power received by the wireless telephone.

18. The wireless telephone of claim 16 wherein the first service provider system is a CDMA digital service provider system and the first

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threshold level used by the signal comparator is -107 dBm for cellular and –105 dBm for PCS.

19. The wireless telephone of claim 16 wherein the timer expires 2 seconds after it begins.

20. The wireless telephone of claim 16, further comprising a preferred roaming list containing operational frequencies of a plurality of possible service provider systems, the system determinator selecting an operational frequency of the second service provider system from the preferred roaming list and disconnecting the wireless telephone from the first service provider system and connecting the wireless telephone to the second service provider system operating at the frequency selected from the preferred roaming list.

21. The wireless telephone of claim 20 wherein the wireless preferred roaming list is stored within the wireless telephone.

22. The wireless telephone of claim 16 wherein the wireless telephone is a dual-mode or dual-band telephone.

23. The wireless telephone of claim 16, further comprising:

a second signal detector structured to receive and measure a second performance level of communication signals;

a second signal comparator structured to compare the second performance level with a second threshold level; and

wherein the timer begins when both the first performance level is below the first threshold level and when the second performance level is below the second threshold level.

24. The wireless telephone of claim 16 wherein the signal detector measures pilot strength.

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25. The wireless telephone of claim 23 wherein the second signal detector measures pilot received power.

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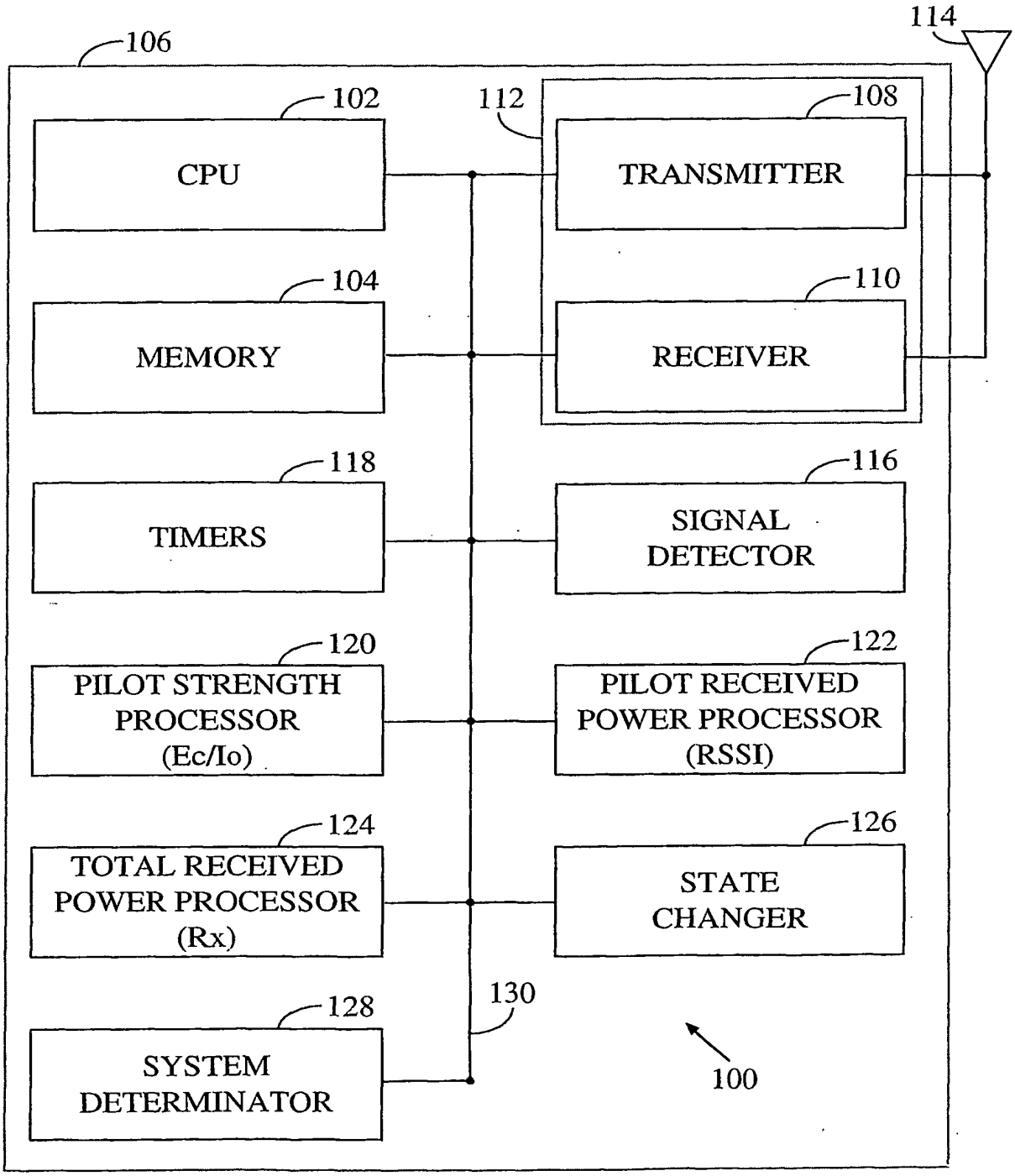

FIG. 1

SUBSTITUTE SHEET (RULE 26)

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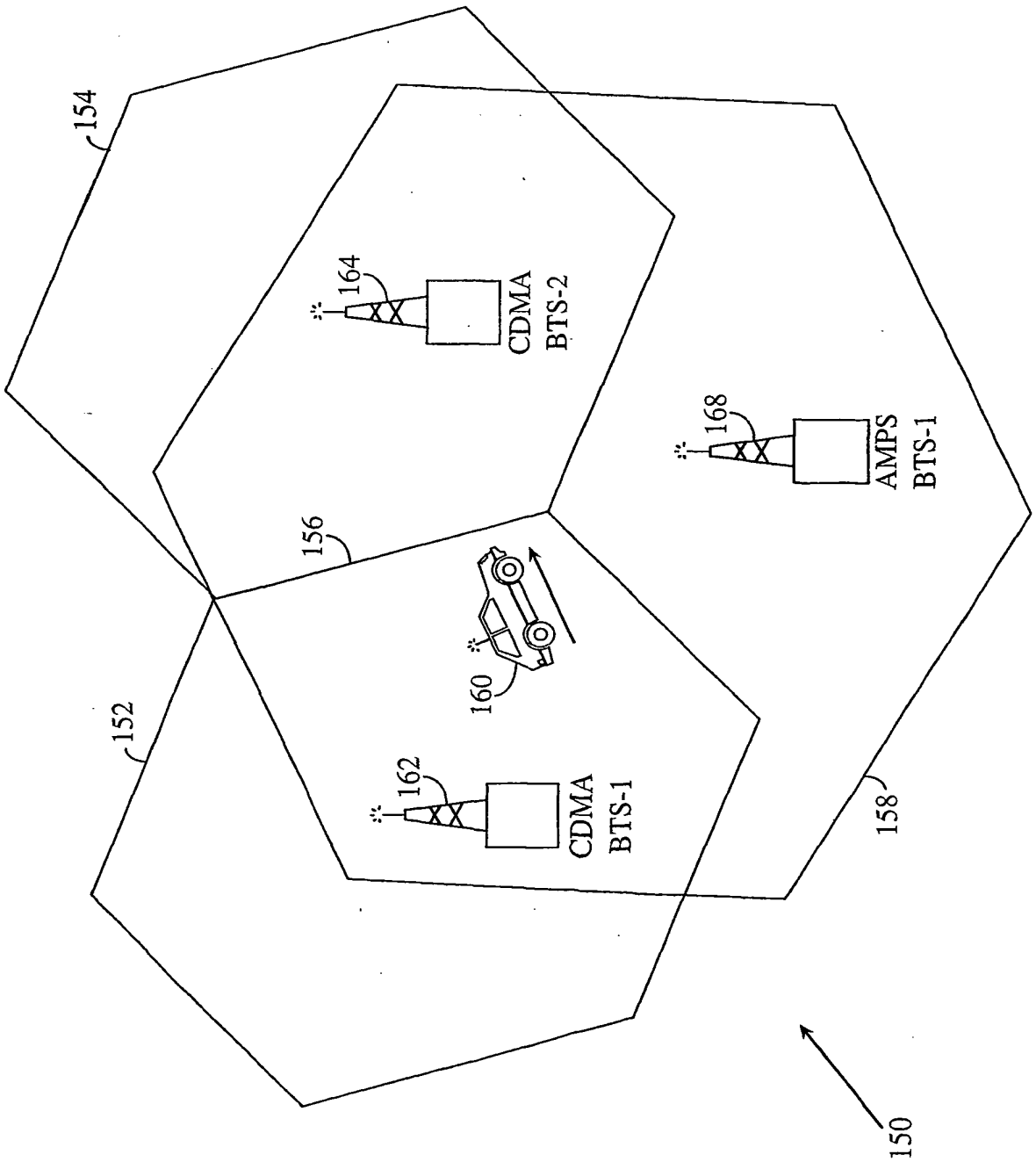

FIG. 2

BNSDOCID: <WO___0103464A1_IA>

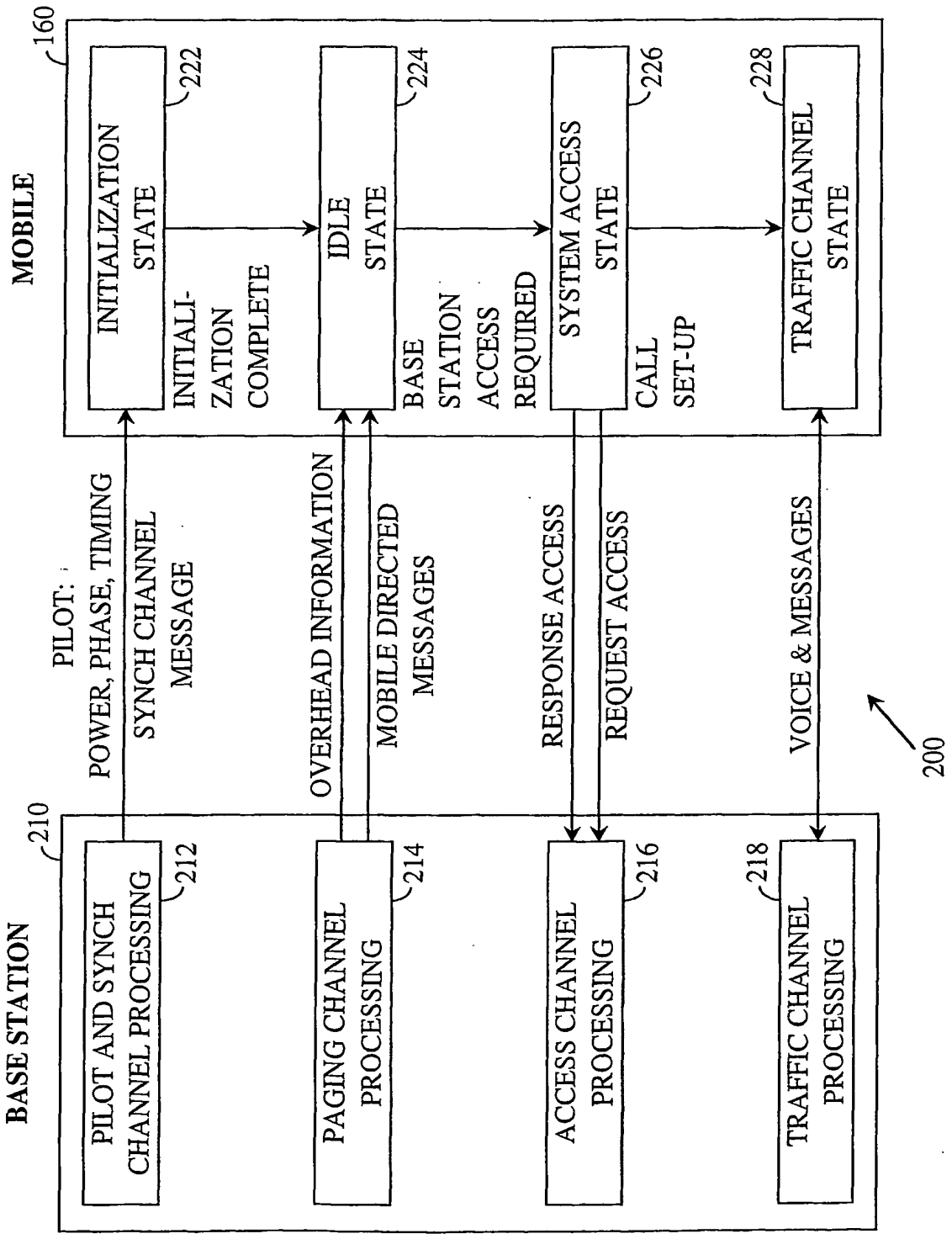

FIG. 3

BNSDOCID: <WO___0103464A1_IA>

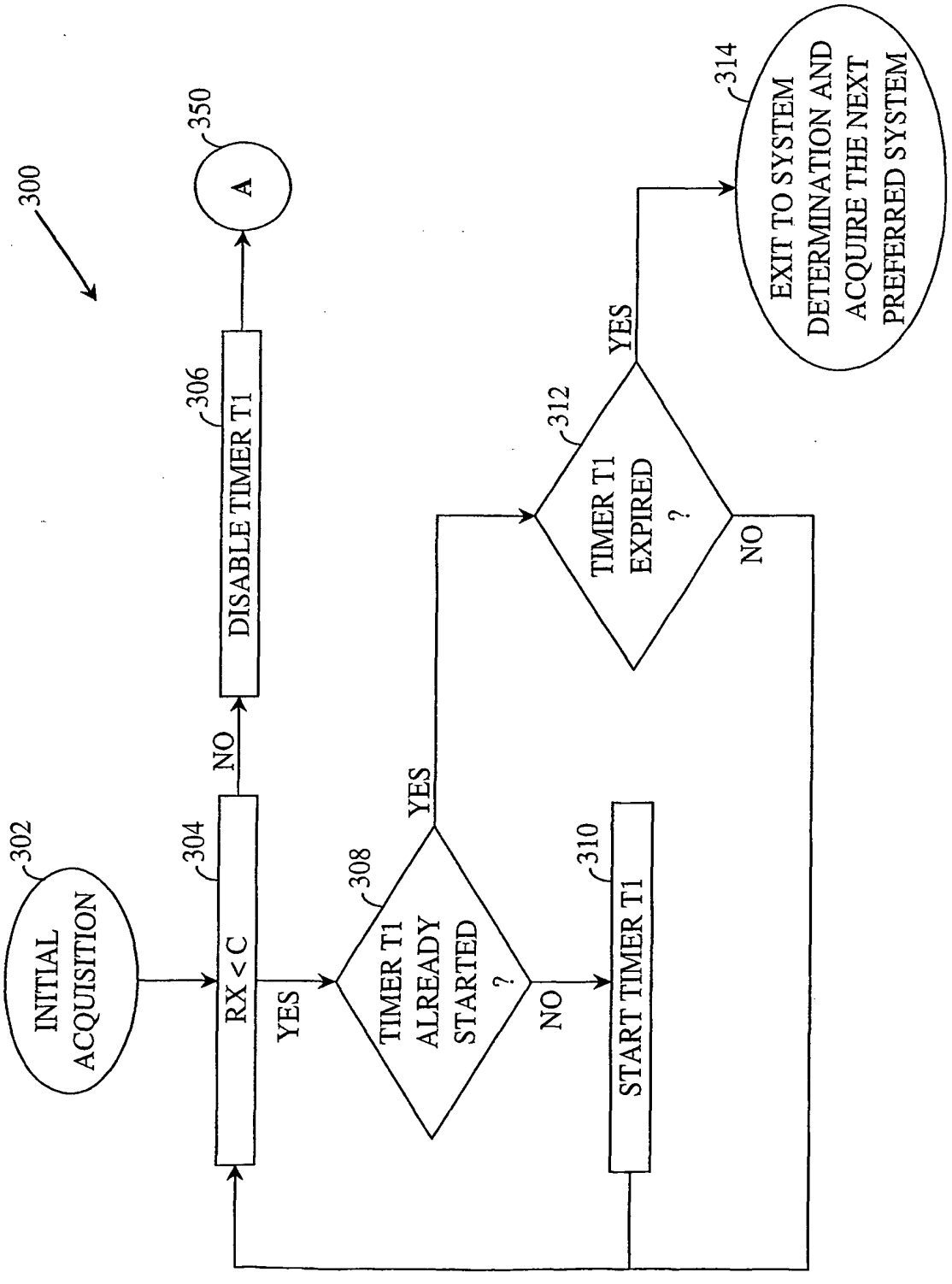

FIG. 4

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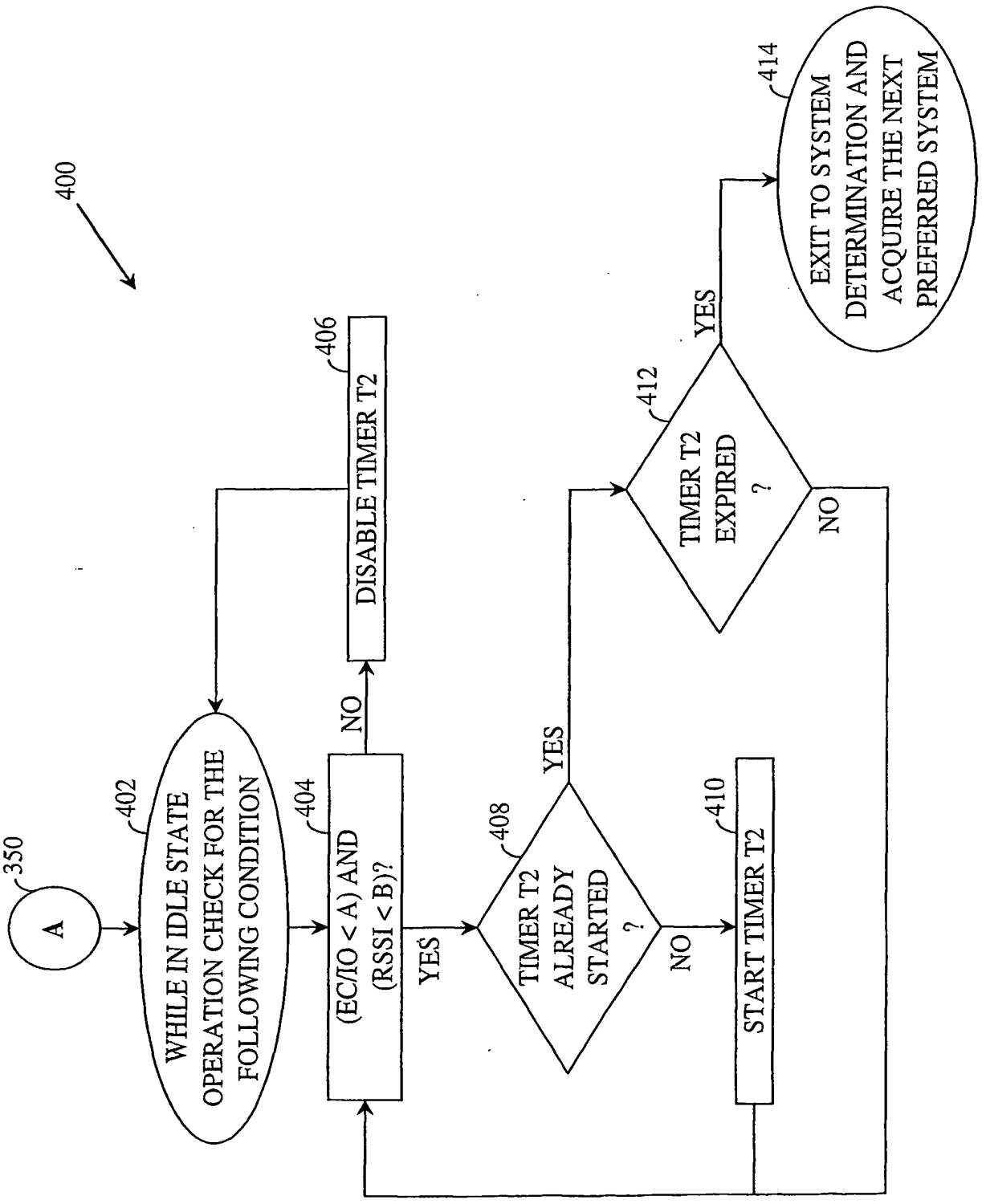

FIG. 5

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INTERNATIONAL SEARCH REPORT

Inte onal Application No
PCT/US 00/18599

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04Q7/38

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5 020 093 A (PIREH) 28 May 1991 (1991-05-28) column 6, line 38 -column 7, line 28	1
Y	WO 98 10617 A (NOKIA MOBILE PHONES LTD.) 12 March 1998 (1998-03-12) page 7, line 15 - line 21 page 10, line 23 -page 11, line 26	1
Y	EP 0 762 669 A (NTT MOBILE COMMUNICATIONS NETWORK INC.) 12 March 1997 (1997-03-12) abstract; figures 4,11,12 column 8, line 3 -column 9, line 13	1,9,16
Y	US 5 260 988 A (SCHELLINGER ET AL.) 9 November 1993 (1993-11-09) column 9, line 26 - line 32; claim 1	1,9,16

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

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Date of the actual completion of the international search	Date of mailing of the international search report
10 October 2000	20/10/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Danielidis, S

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